

Control of Woolly Whiteflies in Lemons with Foliar and Soil-Applied Insecticides

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Abstract

Six foliar insecticide treatments (Esteem, Provado, Applaud, Assail, and Danitol + Dimethoate, and NR-415 spray oil) were evaluated for their control of woolly whitefly infestations in lemons. All of these products were effective in mitigating woolly whitefly populations, although NR-415 did not offer the residual control that the other foliar sprays exhibited. Esteem and Applaud are insect growth regulators that should have little impact on whitefly parasitoids. Provado and NR-415 may initially have a detrimental effect on WWF parasitoids but this impact should be short in duration, while Danitol + Dimethoate will be especially harmful to parasitoids. When used preventively, soil applications of Admire were very effective at preventing WWF colonization. Because parasitoids can be extremely effective in mitigating woolly whiteflies populations during the early phases of colonization, it is recommended that foliar insecticides harmful to WWF parasitoids not be utilized until woolly whitefly colonies are common. However, previous experiences suggest that allowing woolly whitefly populations develop extremely high populations should be avoided.

Introduction

Woolly whitefly (WWF), *Aleurothrixus floccosus*, has been a pest of Arizona citrus in Yuma County since 1996. Since the initial infestation in door-yard citrus in the Yuma Valley, WWF has spread throughout the Yuma Valley and Yuma Mesa. Infestations are usually most severe in late summer through the fall, but are often effectively controlled by insect parasitoids and predators. However, there are times when these natural control agents are not present in sufficient numbers to prevent WWF damage and chemical control is necessary.

Currently, most chemical control of WWF is administered through foliar insecticide applications. The most commonly utilized insecticides for WWF control in Arizona include Esteem (pyriproxyfen), Applaud (buprofenzin), Provado (imidacloprid) and Lorsban (chlorpyrifos). When parasitoid activity is evident, Esteem and Applaud are most frequently used since these tend to be less disruptive of the parasitoid populations. Because these products are insect growth regulators they are slow acting, and when a more rapid control of WWF populations is desired or when there is little parasitoid activity, Lorsban and Provado are used more often. However, in 2003 there were some concerns regarding Lorsban residues on lemon slated for export to Asia. Thus there was interest in identifying an alternative insecticide treatment for Lorsban that would similarly have broad spectrum and rapid activity. In this study Dantol (fenpropathrin) + Dimethoate was evaluated as a Lorsban alternative.

Alternatively to foliar insecticides for WWF management, there has been much interest in using Admire (imidacloprid) as a systemic soil treatment. If applied systemically through the soil, the impact of Admire on parasitoid activity would be negligible and should thus be a good fit in Arizona's citrus IPM system. Although Admire has proven effective against

WWF when applied through drip or emitter irrigation systems, little data exists when applied to flood irrigated citrus.

The goal of this study was to evaluate the efficacy of a several foliar insecticides and soil applications of Admire for control of WWF on flood irrigated citrus.

Materials and Methods

Foliar Test 1

This study was conducted on lemons that were approximately 15-years old grown on the Yuma Mesa near Yuma, Arizona. The test was a randomized complete block design with four replicates. Each plot was 3 rows by 16 trees.

The treatments included: an untreated check, Esteem 0.86EC at 10oz/ac, Provado 1.6F at 19 oz/ac, Applaud (70 WP) at 0.5 lbs/ac and at 0.75 lbs/ac, Danitol 2.4EC at 16 oz/ac + Dimethoate 4E at 2 lbs-ai/ac, and NR-415 spray oil at 1 gal/ac. All the treatments except the oil included Kinetic non-ionic surfactant at 0.1% v/v. The treatments were applied on 15 July 2003 using a standard orchard sprayer calibrated to deliver 100 gal/ac at 100 psi.

Foliar Test 2

This study was conducted on lemons that were approximately 20-years old grown on the Yuma Mesa near Yuma, Arizona. The test was a randomized complete block design with four replicates. Each plot was 3 rows by 10 trees.

The treatments included: an untreated check, Esteem 0.86EC at 10oz/ac, Provado 1.6F at 19 oz/ac, Applaud (70 WP) at 0.5 lbs/ac, and Danitol 2.4EC at 16 oz/ac + Dimethoate 4E at 2 lbs-ai/ac. All the treatments included Kinetic non-ionic surfactant at 0.1% v/v. The treatments were applied on 18 August 2003 using a standard orchard sprayer calibrated to deliver 100 gal/ac at 100 psi.

Soil-applied Test

This study was conducted on 10-year old flood irrigated lemon trees grown on the Yuma Mesa near Yuma, Arizona. The soil type was Superstition Sand. The site selected for this study was a grove that did not have a large resident WWF although small pockets were present, and was situated near a heavily infested grove that would serve as a primary source of whiteflies. The goal was to test Admire to determine if a soil injection would prevent WWF colonization. The test was a randomized complete block design with four replicates. Each plot consisted of sixteen trees.

The treatments included: an untreated check, Admire 2F at 16oz/ac and at 32 oz/ac. Treatments were applied on 23 June, 2003. The injection implement consisted of two injection shanks spaced 6 ft apart and with a forward shank to open the furrow (Figures 1). The treatments were injected approximately 8 in deep at a spray volume of 9 gal/ac at 20 psi. The shanks were positioned laterally to place the product near the tree's drip line (Figure 2).

For all tests, the adult WWF were sampled by in field by counting their number from new fully expanded leaves per plot. The eggs, nymphs and eclosed pupae were estimated by removing five fully expanded leaves per plot, transporting them to the laboratory, and counting their number on the underside of the leaf using a dissecting microscope. All data were analyzed using ANOVA and an F protected lsd ($P < 0.05$).

Results and Discussion

Foliar Test 1

Pre-treatment samples were taken on 14 August. At that time the WWF population was averaging 3.25 adults, 14.7 eggs, 6.57 small nymphs (SN), 5.07 large nymphs (LN), and 2.50 eclosed pupae (EP) per leaf across all plots. The grove utilized in this test had a light to moderate WWF population but appeared to be increasing when treated.

At 8 days after treatment (DAT), Danitol + Dimethoate, NR-415, and Provado had fewer adult WWF than the untreated

(Table 1) All of these product were expected to have some adulticidal activity, while the other products which are insect growth regulators (IGRs), were not expected to exhibit toxic activity towards the adults. No significant differences could be detected in eggs, SN, LN, or EP, primarily because the IGRs had not had time to act and there was a large amount of variability in the samples.

After 16 DAT, the WWF population was increasing in the untreated as evident by the increase in adults and eggs from 8 DAT. At 16 DAT, all of the insecticide treatments had fewer adults than the untreated (Table 1). Only Esteem and Applaud-L (0.5 lbs/ac) failed to differ from the untreated in eggs per leaf. Again since these are IGRs, they are not expected to immediately impact adult WWF and the subsequent egg lay. However, it is not know why Applaud-H (0.75 lb/ac) had fewer eggs per leaf than the untreated. Additionally, since Esteem cause adult whiteflies to lay sterile eggs, it is possible that some of the eggs reported in the Esteem plots were enviable. The number of SN per leaf at 16 DAT were greatest in the Applaud-L plots, followed by the untreated and NR-415 plots and lastly by the other treatments (Table 1).

Against whiteflies, Applaud generally exhibit most of it activity at the LN stage, although SN were very low in the Applaud-H plots, and the number of LN and EP in the Applaud-L plots were greater than in the untreated plots. These results could be interpreted that Applaud at 0.5 lbs/ac may not be a high enough rate or that this rate requires more time to express its activity. However, I am not convinced that the high numbers in the Applaud-L plots may actually be a artifact of the random sampling inadvertently hitting dense pockets of WWF populations, since WWF tend to be clumped in distribution. This supposition is strengthen by the 22 DAT observations where all of the treatment had fewer WWFs than the untreated at all life stage with the exception of Esteem which did not differ from the untreated in LN.

At 28, 36 and 42 DAT, WWF colonization was declining based on the decline in the number of adults and eggs per leaf in the untreated relative to 22 DAT (Table 2). All of the treatments, with a few exceptions were exhibiting good activity towards WWF. Esteem appeared to effectively reduce the overall WWF population among all life stages. Esteem is a juvenile hormone mimic and should cause mortality to large nymphs; but since there was a consistent reduction in SN too, its primary source of activity probably was the result of it causing the adults to lay sterile eggs. Both rates of Applaud also resulted in an overall reduction in the WWF population; it did appear that most of the WWF mortality was occurring at the LN stage, especially at the 0.5lbs/ac rate.

Provado and Dantol + Dimethoate dramatically reduced the WWF population throughout the test period (Table 1 and 2).

Both of these treatments appear to have activity on the adults and nymphs. The fact that adults did not re-infest these plots at 22 DAT when the adult WWF population was extremely high in the untreated suggests that there was not much interplot movement of the adults (Table 1).

NR-415 spray oil was much more effective than anticipated, offering very good control for about 28 days (probably due to a lack of inter-plot WWF movement as previously mentioned). At 28 DAT, it did not differ from the untreated in EP and subsequently at 36 and 42 DAT did not differ from the untreated in adults per leaf (Table 2). Oils are commonly used for WWF control along the California coast. In the low desert there are some concerns that at high temperatures and light intensity oils may cause some phytotoxicity, although none was observed in this trial or for any trials conducted over the past 10 years.

Foliar Test 2

The WWF population in this grove appeared to be moderate in density and extremely clumped in distribution. On 14 August, before any insecticide applications, the Provado plots had significantly more eggs per leaf than the other plots, while Danitol + Dimethoate had more LN (Table 3). Casual in-field observation suggested that these differences are more an artifact of sampling rather than “true” differences. Regardless, by 9 DAT these differences were not evident (Table 3). At 9 DAT, all of the treatments appeared equally effective in controlling the WWF population, although the adults did not appear to be affected by Applaud, which was expected. At 17 and 23 DAT, all of the treatments had fewer eggs, SN, LN, and EP than the untreated and only Applaud failed to contain fewer eggs than the untreated at 29 DAT (Table 4). By 37 DAT, there was a great deal of variability in the test and the only statistical difference occurred for LN, where all of the treatments were lower than the untreated (Table 4).

Although the products tested in both foliar tests differ in their modes of activity, and the WWF life stages they impact, the end results were similar. Esteem, Applaud, Provado, Danitol + Dimethoate, and NR-415 Oil are all valid products for controlling WWF in Arizona citrus.

Soil-applied Test

Adult WWF did not migrate into this test in large numbers. The peak flight occurred at 44 day after treatment (DAT) at which time they were averaging a little more than 4 adults per flush, after which their number declined (Figure 3). At no time did we detect a statistical difference among the treatments in the number of adult WWF (Figure 3). However, it was evident that these adults had migrated into the field and had the number of been greater, differences may have been detectable.

Although the adult population was low, there was significant egg ovipositioning. Egg laying peaked at 41 eggs per leaf at 44 DAT (Figure 4), which coincides with the peak adult flight (Figure 3). At 38, 44 and 58 DAT, there were significantly fewer eggs per leaf in the Admire treatments relative to the untreated (Figure 4). This suggests that Admire was having an impact on the adult WWFs either via adult mortality, which we could not detect, or via preference by deterring ovipositioning in the Admire treatments (Figure 4).

Table 1. Mean number of adult and immature woolly whiteflies on fully expanded lemon leaves 8, 16 and 22 DAT, Foliar Test 1.

Treatment	23 July (8 DAT)					31 July (16 DAT)					8 August (22 DAT)				
	Adults	Eggs	SN	LN	EP	Adults	Eggs	SN	LN	EP	Adults	Eggs	SN	LN	EP
Untreated	1.75ab	18.50a	12.00a	1.25a	3.50a	23.75a	53.75a	7.00b	13.00ab	8.50b	134.75a	385.25a	105.25a	13.50a	15.50a
Esteem	1.50ab	10.00a	3.00a	0.75a	9.00a	0.50c	21.25ab	1.00b	2.25c	0.00b	6.00b	9.75c	4.50b	11.50a	2.25bc
Provado	0.00c	21.25a	0.50a	1.00a	3.25a	3.50bc	6.00b	0.50b	0.00c	1.75b	6.75b	0.00c	0.00b	0.00b	6.75b
Applaud-L	1.75ab	5.75a	3.00a	0.75a	1.25a	12.00b	37.25a	19.50a	16.25a	23.25a	2.00b	59.75b	0.00b	0.00b	5.25b
Applaud-H	2.75a	20.50a	1.50a	1.50a	1.25a	3.00bc	8.00b	0.50b	1.50c	0.00b	5.50b	11.50c	0.75b	1.75b	0.00c
NR-415	0.00c	10.00a	4.75a	6.25a	6.50a	0.50c	9.25b	7.50b	8.25b	0.50b	9.25b	24.25b	1.00b	4.00b	4.00c
Danitol+Dimethoate	0.75bc	6.25a	1.00a	1.00a	1.00a	0.00c	1.25b	0.00b	0.75c	0.00b	1.50b	0.00c	0.00b	0.00b	0.00c

Means in a column followed by the same letter are not significantly different; ANOVA, F protected LSD ($P < 0.05$).

Table 2. Mean number of adult and immature woolly whiteflies on fully expanded lemon leaves 28, 36 and 42 DAT, Foliar Test 1.

Treatment	12 August (28 DAT)					20 August (36 DAT)					26 August (42 DAT)				
	Adults	Eggs	SN	LN	EP	Adults	Eggs	SN	LN	EP	Adults	Eggs	SN	LN	EP
Untreated	23.25a	190.75a	149.75a	61.59a	31.50a	15.75a	142.75a	138.75a	56.75a	93.25a	14.50a	95.75a	33.25ab	55.75a	44.75a
Esteem	3.00b	83.00b	25.50c	0.00c	1.25b	0.00b	7.50c	2.25c	11.00c	1.50d	3.00b	3.50c	5.75c	0.00b	9.75c
Provado	1.00b	33.75b	0.00c	1.25c	1.75b	1.50b	21.50c	0.00c	0.00c	17.50c	0.00b	7.50c	8.00bc	0.00b	0.00c
Applaud-L	1.50b	81.00b	58.50b	21.75b	4.75b	1.00b	85.50b	48.75b	6.25c	17.25c	1.50b	43.75b	0.00c	0.00b	0.00c
Applaud-H	2.00b	11.25b	22.25c	21.25b	0.00b	1.00b	7.50c	13.00c	12.75c	5.00d	0.00b	3.50c	5.75c	0.00b	3.50c
NR-415	12.50 b	43.50b	45.00b	29.00b	15.75ab	12.25a	65.25b	33.00b	21.75b	40.00b	13.25a	49.75b	50.50a	43.00a	23.25 b
Danitol+Dimethoate	0.75b	6.75b	0.00c	0.00c	0.00b	0.00b	4.00c	0.00c	0.00c	0.00d	1.25b	3.25c	0.00c	0.00b	5.00c

Means in a column followed by the same letter are not significantly different; ANOVA, F protected LSD ($P < 0.05$).

Table 3. Mean number of adult and immature woolly whiteflies on fully expanded lemon leaves precount, 9 and 17 DAT, Foliar Test 2.

Treatment	14 August (precount)					27 August (9 DAT)					4 September (17 DAT)				
	Adults	Eggs	SN	LN	EP	Adults	Eggs	SN	LN	EP	Adults	Eggs	SN	LN	EP
Untreated	2.40a	21.60b	0.40a	4.20b	18.80a	9.25ab	224.25a	105.75a	49.25a	58.50a	6.50a	405.25a	148.25a	67.50a	41.75a
Esteem	6.80a	6.40b	0.00a	0.60b	8.60a	3.50b	10.25b	0.00b	2.75b	7.00b	3.00a	7.00b	0.00b	0.75b	3.00b
Provado	5.20a	570.00a	69.00a	2.80b	0.00a	6.00b	4.00b	0.00b	0.00b	14.50b	6.00a	3.50b	0.00b	0.00b	0.00b
Applaud	8.80a	9.00b	0.00a	0.80b	106.00a	19.00a	4.00b	0.00b	0.00b	7.50b	9.00a	15.00b	0.00b	0.00b	2.50b
Danitol+Dimethoate	9.40a	35.00b	28.00a	79.00a	41.80a	0.50b	3.75b	0.00b	2.00b	1.50b	0.50a	0.00b	0.00b	0.00b	9.50b

Means in a column followed by the same letter are not significantly different; ANOVA, F protected LSD ($P < 0.05$).

Table 4. Mean number of adult and immature woolly whiteflies on fully expanded lemon leaves 23, 29 and 37 DAT, Foliar Test 2.

Treatment	10 September (23 DAT)					16 September (29 DAT)					24 September (37 DAT)				
	Adults	Eggs	SN	LN	EP	Adults	Eggs	SN	LN	EP	Adults	Eggs	SN	LN	EP
Untreated	6.25a	196.75a	113.50a	43.50a	10.00a	5.50ab	89.00a	136.25a	163.50a	56.50a	0.25a	58.75a	36.25a	14.50a	8.00a
Esteem	1.75a	9.00c	6.25b	8.50b	0.00a	0.75b	2.00b	3.50b	0.00b	4.25b	0.75a	6.00a	4.50a	2.25b	2.50a
Provado	3.25a	0.00c	0.00b	0.00b	6.75a	0.50b	4.25b	1.75b	0.00b	4.50b	0.00a	49.50a	1.25a	0.00b	0.50a
Applaud	26.50a	67.75b	3.25b	4.25b	1.00a	13.75a	62.00a	1.50b	0.25b	1.25b	2.50a	39.75a	0.00a	0.00b	6.00a
Danitol+Dimethoate	0.25a	1.00c	0.00b	0.00b	21.00a	1.00b	1.50b	0.00b	0.25b	9.50b	0.25a	51.00a	10.75a	0.50b	7.25a

Means in a column followed by the same letter are not significantly different; ANOVA, F protected LSD ($P < 0.05$).



Figure 1. Soil applied insecticide injection implement for flood irrigated citrus.



Figure 2. Soil insecticide injection in flood irrigated citrus.

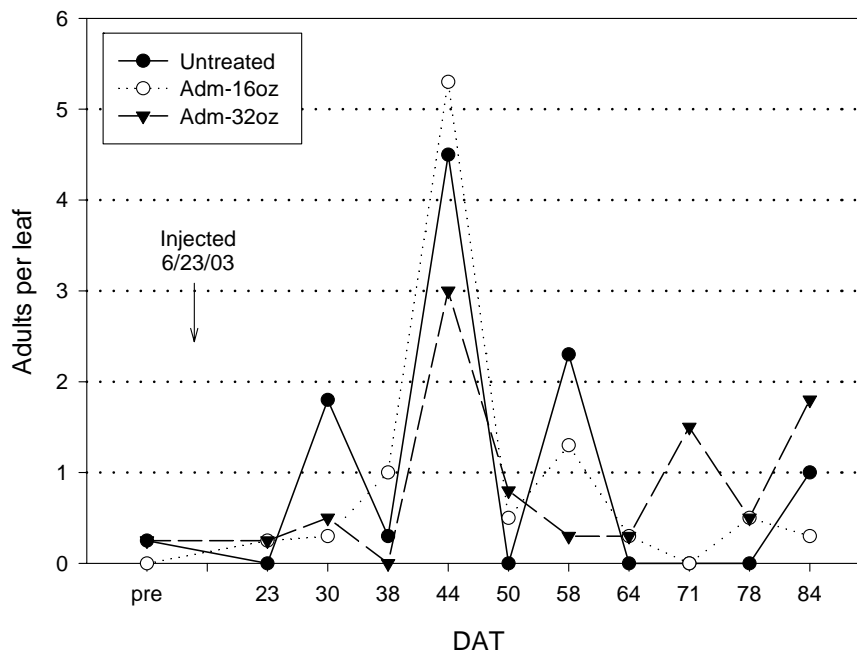


Figure 3. Number of adult WWF per lemon leaf following soil injections of Admire at 16 and 32 oz/ac. Data points with an * are statistically different based on an F protected lsd, $P < 0.05$.

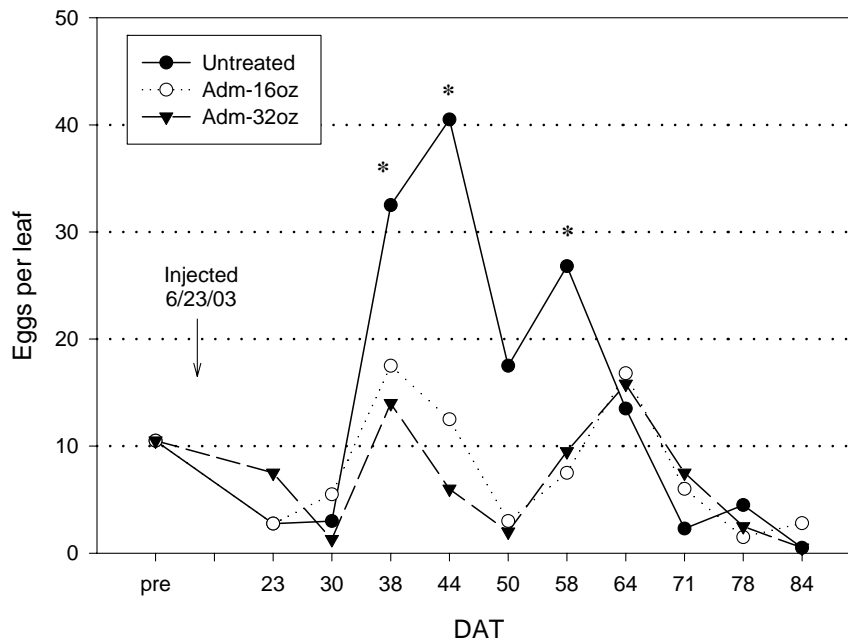


Figure 4. Number of WWF eggs per lemon leaf following soil injections of Admire at 16 and 32 oz/ac. Data points with an * are statistically different based on an F protected lsd, $P < 0.05$.

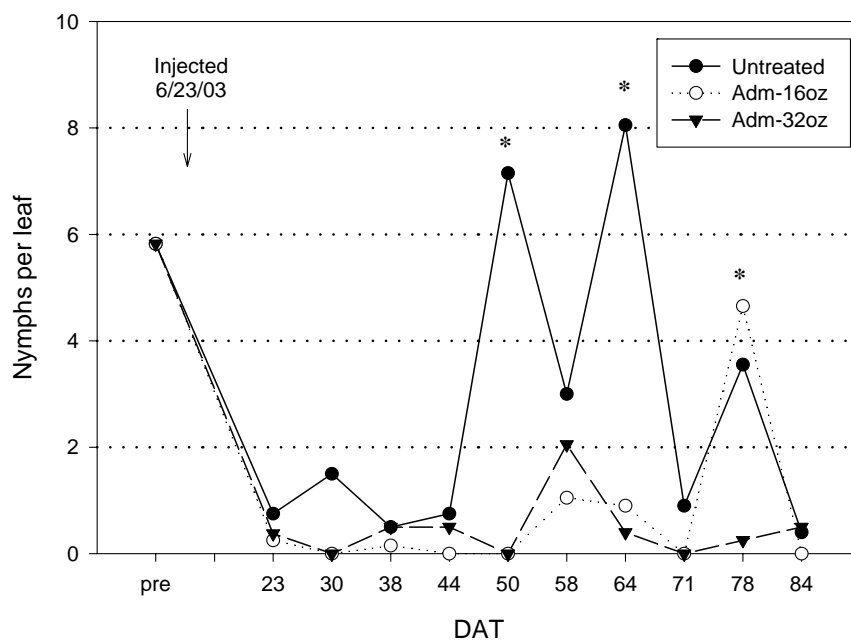


Figure 5. Number of WWF nymphs per lemon leaf following soil injections of Admire at 16 and 32 oz/ac. Data points with an * are statistically different based on an F protected lsd, $P < 0.05$.

Figure 6. Number of WWF eclosed pupae per lemon leaf following soil injections of Admire at 16 and 32 oz/ac. Data points with an * are statistically different based on an F protected lsd, P<0.05.

